TYPOLOGY OF *Pinus sylvestris* L. FORESTS IN SPAIN

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SUMMARY

The wide range of ecological factors such as climate, soils, topography, geographical position that can be found in the Iberian peninsula has produced a high diversity of *Pinus sylvestris* L. communities. In this paper the Scots pine communities in Spain have been reviewed and the different geobotanical interpretations made by Spanish botanists have been analysed. There is no unanimity on how to classify these forests, and some of them have not been included in geobotanical or phytosociological classification because they have been considered like reforestations in climax areas of the other species.

KEY WORDS: *Pinus sylvestris* L.
Typology
Geobotany
Phytosociology
Spain

EVOLUTION OF *Pinus sylvestris* L. FORESTS IN THE IBERIAN PENINSULA SINCE THE LAST GLACIATION

Costa Tenorio *et al.* (1990) maintain that from the end of the last great glaciation, the Würm [1], about 15-13000 years BP [2] «the bioclimatic zonation of the Iberian peninsula has broadly coincided with that of the present day». Thus there is a zone of Atlantic influence centred in the northeastern quadrant and the Cantabrian seaboard, with extensions into the Pyrenees and the Sistema Central and northern Sistema Ibérico mountain ranges. There is a second, Mediterranean, zone with greatest aridity in the southeastern quadrant, and an extensive inland transitional zone (sub-Atlantic-sub-Mediterranean), with highly continental areas characterised by wide temperature fluctuations and local arid enclaves. The latter is where *Pinus sylvestris* woodland has been - and still is - important. Here the expansion of

[1] According to the authors and the regions studied, the Würm lasted from 100,000 to 15-13000 years BP.
[2] BP: by convention, BP means «before present», where «present» is the year 1950.

woodland since the last glacial period, has gradually taken place over 7000 years, with slight advances and retreats of the open, heliophilous woodland of birch, pine and *Juniperus* spp. (treelike: *J. communis*, *J. thurifera*, or creeping junipers *J. communis* subsp. *alpina*, *J. sabina*), until forest formation became consolidated (Costa Tenorio *et al.*, 1997).

During the cold periods of the last Ice Ages, a number of species and vegetation communities of boreal origin spread into the Iberian peninsula. Among these, extending as far as areas of the Portuguese coastline (Teixera, 1944) and Sierra Nevada, was *Pinus sylvestris.* Cold coniferous forests of *Pinus sylvestris* and/or *Pinus uncinata* Mill. and birch during the preboreal period [3] between 10,200 and 8,800 years BP were important. The subsequent rise in temperature and humidity during boreal (8,800 - 7,500 BP) and Atlantic (7,500 - 4,500 BP) periods resulted in the gradual expansion of deciduous broadleaf forest: oak, beech and mixed woodland (spreading from their refugia in low-lying coastal areas, Gaussen, 1933) displacing the coniferous forest on all the northern slopes of the Cordillera Cantábrica and north of the Pyrenees. Pinewoods (probably *P. sylvestris*) on these slopes would have been limited to topography which was difficult for broadleaf species to colonise (Maldonado, 1994; Costa Tenorio *et al.*, 1997), as it happening with those currently found in enclaves north of the Pyrenees (Gruber, 1979, 1991). At the same time, on the southern slopes, pines continued to occupy zones with a more continental climate. The subsequent reduction of its range, while possibly due to climate changes in less continental areas, may have been a result of human activities (Maldonado, 1994; Costa Tenorio *et al.*, 1997).

The evolution of montane vegetation from the Late Glacial onwards shows similarities with the above-mentioned situation on the southern slopes of the Cordillera Cantábrica and the Pyrenees, and in the Sistema Central and the Sistema Ibérico, where the markedly continental climate has allowed *Pinus* woodland to survive throughout the Holocene (Peñalba, 1989; Franco, 1995; Gómez-Lobo, 1997; Costa Tenorio *et al.*, 1997).

TYPES OF SCOTS PINE FOREST IN THE IBERIAN PENINSULA: CHOROLOGY AND PHYTOSOCIOLOGICAL TREATMENT

When attempting to establish the natural range of Scots pine in the Iberian peninsula problems arise as there is no consensus among botanists about the origin and the role in the dynamic of the vegetation of certain stands and their appropriate position in vegetation classification. The mapping carried out by Ceballos *et al.* (1966) which makes a distinction between natural and reforested stands (Fig. 1) is not universally accepted. Many botanists consider that many of the stands regarded by Ceballos *et al.* (*op. cit.*) as natural are actually artificial, originating from early reforestations; these stands have therefore not been regarded within the phytosociological classification in the following description.

Following is a description of each of the natural areas of Scots pine in the Iberian peninsula, noting various aspects of distribution, ecology, problems and the most recent and commonly accepted phytosociological treatments. Sections are ordered according to the distribution given in Figure 1.

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[3] Following the criteria of Mangerud *et al.* (1974).

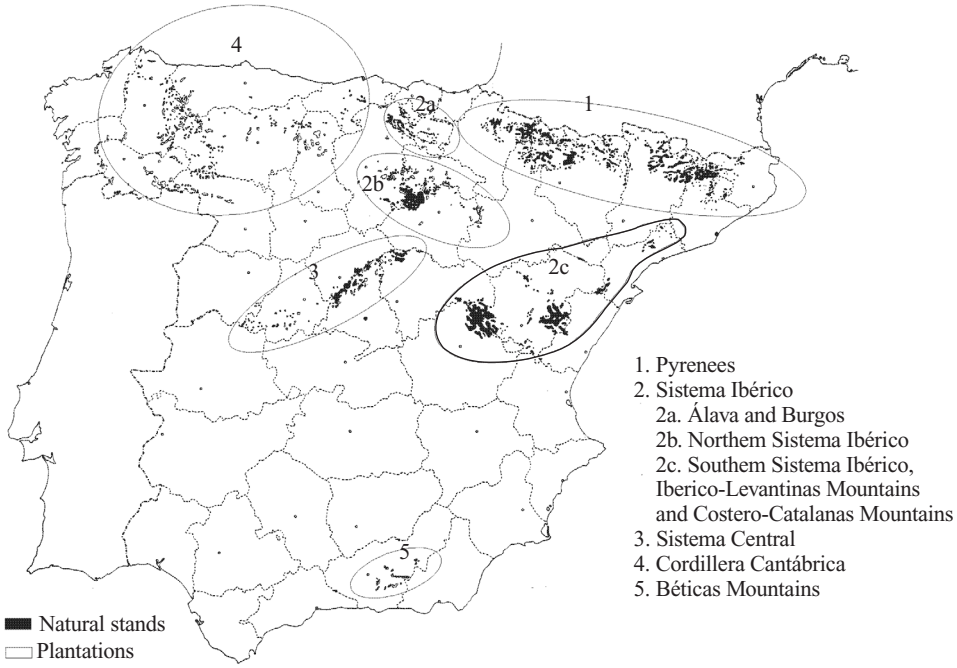

Fig. 1.–Distribution of *Pinus sylvestris* L. in Spain
Distribución de P. sylvestris L. en España

Source: Ceballos *et al.* 1966.

1. Scots pine in the Pyrenees

Scots pine stands in the Pyrenees form the most extensive of all the areas in the Iberian peninsula. They are found mainly on the southern slopes from near Pamplona (Navarra) on the west, to Ripoll, Gerona (Cataluña) on the east. Half are in the province of Huesca, and the rest are distributed between the provinces of Gerona, Lérida, Barcelona, Navarra and northern Zaragoza. Most grow over calcareous substrates, on south-facing slopes, often in mixed stands with *Pinus uncinata*, *Abies alba* Miller, *Fagus sylvatica* L., *Quercus humilis* Miller (= *Quercus pubescens* Willd.) and even with *Quercus ilex* L. subsp. *ballota* (Desf.) Samp**.**

In this mountain range there is a great difference between the vegetation on the northern and southern aspects. The lower-mountain slopes in the north are dominated by *Fagus sylvatica* and *Abies alba*, with *Pinus sylvestris* occurring infrequently, whilst on the southern side the presence of pine is extensive. This contrast is due to the higher light levels and more continental climate on the south side. On the north side of the Pyrenees, the moist winds and frequent mists blow in unhindered from the Atlantic Ocean favouring

beech woods, while to the south, the «oceanic» influence from the Atlantic or Mediterranean decreases with increasing distance inland.

Pinewoods occupy a belt roughly between 1000 and 1700 m (Gruber, 1981; Dupias, 1985; Rivas-Martínez, 1987; Costa Tenorio *et al.* 1997), though some writers have proposed other altitudes: 1000-1600 m (Montserrat, 1976); 1200-1500 or 1700 m depending on aspect or slope (Alvera, 1990). They may exceptionally go beyond these limits, reaching as high as 2000 m in dry local conditions (Montserrat, 1976) and as low as 3-400 m, invading the territory of the oak (Costa Tenorio *et al.* 1997).

Different schemes of classification place varying emphasis on the phytogeographical significance, the geobotanical role, and the dynamism of these woodlands. All authors consider montane pinewoods to be climax communities, while the most important discrepancies concern those at lower altitudes as it can be seen in table 1. Thus Rivas-Martínez (1987) and Rivas-Martínez and Molina (1997) distinguish three series of montane Scots pinewoods, but do not mention those at lower altitude, perhaps not considering them to be natural [4]. On the other hand, other authors (Dupias, 1985; Bolòs, 1960; Vigo, 1979, 1996; Vigo and Ninot, 1987; Villar and Benito, 1994; Costa Tenorio *et al.* 1997), do consider most of these sub-montane pinewoods to be natural, including climax vegetation and also, the majority, secondary forests, since the pine has spontaneously colonised other woodland types.

Montane pinewoods

Rivas-Martínez (1987) and Rivas-Martínez and Molina (1997) include the montane pinewood series within the *Pino-Juniperetea* Rivas-Martínez 1964 class. However, Vigo (1979) rejects this for the Pyrenees, except in some enclaves, and considers that Pyrenean montane pinewoods, which sometimes reach sub-alpine altitudes, should be placed exclusively within the *Vaccinio-Piceetea* Br.-Bl. 1939. Villar and Benito (1994), taking an eclectic position, assume that there are pinewoods belonging to both classes.

Another important difference of opinion is that Rivas-Martínez (1987) recognises three series, while the majority of authors recognise four different formations combined into two groups according to their ecological preferences (Table 1).

Dupias (1985) describes the climax series of montane pinewood, where he claims that there are frequent incursions into the lower levels of the sub-alpine zone. The mesophile series is the most humid form of pinewood:

«It occupies considerable areas on the southern side, at all orientations, between 1000 and 1700 metres [and occurs] in some places on the northern side [and] belongs in a sunny and fairly dry climate (a little more than that necessary for beech to become established)».

There are transitions with meso-xerophile beech woods and over all with mesophile spruce woods. On the other hand the xerophile series occupies:

«the driest mountain sites. It is only found on the southern side (from the Cerdaña area to Aragón), on south-facing slopes, and in very windy areas, mainly in higher montane situations. The nature of the substrate (calcareous or non-calcareous) and the geographical position within the range (eastern or central) influence its composition and its regression state».

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[4] Although in 1963 Rivas-Martínez referred to its «natural presence, from the domain of the *Quercion pubescentis*, on the pre-Pyrenees».

TABLE 1

DIFFERENT OPINIONS ON THE FORMATIONS OF *Pinus sylvestris* FORESTS IN THE PYRENEES RANGE

Diferentes hipótesis sobre la formación de los bosques de Pinus sylvestris L. en los Pirineos

Mountain pinewoods Approx. > 1000 m		Rivas-Martínez (1987)	Dupias (1985); Vigo and Ninot (1987); Costa Tenorio *et al.* (1997)
	basic substrates	between 1000 and 1700 m: *Echinosparto horridi-Pineto sylvestris sigmetum* Rivas-Martínez 1987	xerophile or south-slope pinewoods, *Echinosparto-Pinetum sylvestris*
		beteween 1100 and 1600 m: *Polygalo calcareae-Pineto sylvestris-sigmetum* (Vigo 1974) Rivas-Martínez 1983	mesophile or north-slope pinewoods *Polygalo-Pinetum sylvestris*
	acid substrates	between 1300 and 1800 m: *Veronico officinalis-pineto sylvestris sigmetum* Rivas- Martínez 1968.	xerophile or south-slope pinewoods, *Veronico-Pinetum sylvestris*
			mesophile or north-slope pinewood *Hylocomio-Pinetum sylvestris*
sub-montane or sub-Mediterranean pinewoods approx. < 1000m	overall alkaline substrates	Dupias, 1985; Bolòs, (1960); Vigo (1979, 1987, 1996); Villar & Benito, 1994; Costa Tenorio *et al.* 1997: successional pinewoods.	
		Vigo & Ninot (1987) (above 600 m, and could go up 1400 m) *Buxo-Quercetum pubescentis hylocomio pinetosum* O. Bolòs & P. Montserrat 1984.	
		Vigo (1996): 1. *Buxo-Quercetum pubescentis*.- 800-1.200-1.300 m (1.500) a) typical sub-association b) *fagetosum* c) *hylocomio-pinetosum* O. Bolòs & Montserrat 1984 d) *festuco-pinetosum* Molero & Vigo 19812. 2. *Teucrio scorodoniae-Quercetum petraeae* Lapraz 1966, Emend. O. Bolòs 1983, *vaccinio-pinetosum* Vigo 1996 3. *Luzulo nivae-Fagetum* (Suspl. 1942) Br.-Bl. 1952. 4. *Brachypodio-Fraxinetum excelsioris* Vigo 1968, between 975 and 1350 m, *pinetosum sylvestris*, 5. *Hedero-Tilietum platyphylli* Vigo & Carreras 1983. *pinetosum sylvestris*	

It is distinguished from the mesophile series by the absence of montane beech wood species in the understorey and in the mossy layer.

Vigo and Ninot (1987) make a similar classification to that of Dupias (1985), but use a rather different terminology. They use the term north- and south-facing slope pinewoods for those that Dupias calls mesophiles and xerophiles respectively. Within the north-facing slope pinewoods they distinguish two associations: mossy pinewoods of the typical *Hylocomio-Pinetum catalaunicae* Vigo 1968 association [5], found from under 1100 m to over 1600 m over acid substrates, and pinewoods over limestone of the *Polygalo-Pinetum sylvestris* (Vigo 1974) Rivas-Martínez 1983 association. Higher up there are transitional communities with sub-alpine woodland of mountain pine, and lower down there are mixtures between pinewoods and the oak with box (*Buxus sempervirens*) series. In the second group, within the south-facing slope pinewoods situated between about 1,500 m and 1,800 m, they identify the acid *Veronico-Pinetum sylvestris* Rivas-Martínez 1968 association with characteristic plants such as *Juniperus communis* L., *Veronica officinalis* L., *Deschampsia flexuosa* (L.) Trin. and *Cytisus oromediterraneus* Rivas-Martínez (= *Genista purgans* auct.). This is distinguished from those pinewoods of calcareous south-facing slopes, *Echinosparto-Pinetum sylvestris*, accompanied by box (*Buxus sempervirens* L.), juniper (*Juniperus communis* L.) and usually broom *Echinospartum horridum* (Vahl) Rothm. (= *Genista horrida* (Vahl) DC.)

Costa Tenorio *et al.* (1997) accept the Dupias (1985) description and division. They consider that between 1,000 m and 1,700 m Scots pine forms pure stands, or may form part of other woods - beech, spruce or *Pinus uncinata.* It may even in other cases be a serial stage of these, as is claimed by Villar and Benito (1994) in stating that Scots pine is also present in other communities. For example, in sub-Mediterranean beechwoods on limy soil (*Buxo-Fagetum sylvaticae* Br.-Bl. & Susplugas 1937, *Scillo lilio-hyacinthi-Fagion* (Oberdorfer 1957) Rivas-Martínez *et al.* 1984) at around (900)-1200-1600 (1800) m they report «mixed stands of beech and Scots pine are extensive».

Vigo (1996) has kept the separation of siliceous pinewoods in the two series quoted, but almost at the same time Rivas-Martínez and Molina (1997) disagreed with previous divisions and proposed that the *Veronico-Pinetum sylvestris* association be assimilated to the *Hylocomio-Pinetum sylvestris*, so recognising one series of siliceous pinewoods.

Sub-montane pinewoods

Dupias (1985) distinguishes a foothill zone sub-series that is the transition to the pinewoods of the dry montane level. It is found mainly on the southern side of the range in the upper part of the foothill zone, reaching 1,200 m. Scots pine occurs in variable mixture with oaks (*Quercus pubescens (= Q. humilis)*, *Quercus faginea* Lam. subsp. *faginea*) and can even form almost pure stands on the poorest soils. Dupias also maintains that the pine seems to be favoured by human activity, since it establishes itself most easily in heavily degraded oakwoods. Costa Tenorio *et al.* (1997) accept this division: below 1,000 m are found what they term «sub-Mediterranean pinewoods» (comparable to Dupias' foothill zone sub-series), which can:

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[5] *Pinus catalaunica* = *Pinus sylvestris* L. var. *catalaunica* Gaussen.

«dominate the landscape, mingling with various species of oak (*Quercus faginea*, *Q. pubescens*) or with other pines such as *Pinus nigra*, *P. pinaster* or even *P. halepensis* and holm oak (*Quercus ilex* subsp. *ballota*) at the eastern end of the Pyrenees».

Like Dupias, they regard these stands, with a few exceptions, as having «a markedly regression character».

In the submontane zone of the southern side of the eastern Pyrenees, which includes a wide area between 600 m and 1,400 m, Vigo and Ninot (1987) distinguish various types of Scots pine which are plentiful on north-facing slopes, and even appear on some upper south-facing slopes. They describe these under the term meso-xerophile zonal woods and regard them as much more important than *Quercus humilis* woodland, where there are marked physiognomic differences, though floristically they are «closely related». For this reason they regard them as a particular sub-association of *Quercus humilis* (= *Q. pubescens*) with box: *Buxo-Quercetum pubescentis* Br.-Bl. *hylocomio pinetosum* O. Bolòs & P. Montserrat 1984. They also consider that the pinewoods have been partly favoured by human activity.

Vigo (1996) published a study of the different vegetation communities of the Vall de Ribes (Gerona). He reports the occurrence of a group of «transition pinewoods» which are difficult to position in the taxonomic classification used and which he finds impossible to classify. There are also other pinewoods that he considers should be included phytosociologically in the *Querco-Fagetea* Br.-Bl. & Vlieger 1937 class, as they were years earlier in Vigo (1979). Five associations, with various sub-associations, are distinguished (Vigo, 1979):

1. *Buxo-Quercetum pubescentis*.- typical submontane woods (between 800 and 1,200-1,300 m and up to 1,500 m on south-facing slopes): oakwoods, pinewoods (generally secondary) and very poor beechwoods. The sub-associations where pine is present are:
   a) typical, with two variants: one with Scots pine, regarded as almost certainly secondary, and another characterised by *Pulmonaria longifolia* (Bast.) Boreau which is often a mixed forest of oak and pine.
   b) *fagetosum,* with a variant dominated by *Pinus sylvestris.*
   c) *hylocomio-pinetosum* O. Bolòs & Montserrat 1984, including Scots pinewoods in the shady enclaves, especially those of north-facing slopes.
   d) *festuco-pinetosum* Molero & Vigo 1981: pinewoods established on calcareous and rich substrates with a certain tendency towards the association *Polygalo-Pinetum.* It is also remarked that «as with the previous sub-association, it may be assumed that these pinewoods are sometimes natural, but that they have most often become established as a result of human activity».
2. *Teucrio scorodoniae-Quercetum petraeae* Lapraz 1966, Emend. O. Bolòs 1983, sub-association *vaccinio-pinetosum* Vigo 1996, interpreted as a transition towards Scots pinewoods.
3. *Luzulo nivae-Fagetum* (Suspl. 1942) Br.-Bl. 1952. It is noted of this association that «there can be found a very limited amount of transition communities between the acid beechwoods and Scots pinewoods (...) the substitution of the beech by the conifer may be due in part to human influence».
4. *Brachypodio-Fraxinetum excelsioris* Vigo 1968, found between 975 and 1350 m. It is noted that «there are aspects of the association made up of oakwoods,

pinewoods or birchwoods». For the pinewoods of some north-facing slopes a new sub-association *pinetosum sylvestris* is described, where the dominance of Scots pine is associated with the abundance of some mosses. This could be the result, though only partially, of reforestation.

5. *Hedero-Tilietum platyphylli* Vigo & Carreras 1983. These are mixed woods often dominated by ash, lime, or oak, but with elm, cherry, *Quercus humilis*, stalked cupped oak, maple, aspen and even pine. A new, fairly atypical sub-association, *pinetosum sylvestris*, is proposed, where dominant Scots pine is accompanied by plants and mosses characteristic of acidic conditions.

The Scots pine, as a tree with a wide ecological amplitude, easily invades the potential territory of deciduous trees across a very extensive environmental range. For this reason the authors have taken this into account and describe the contacts or ecotones as a sub-association of the type of woodland they are describing, since the communities are described basically in terms of their accompanying flora and certain environmental conditions, without taking physiognomy into account. As a result, in classification systems, Scots pine woods are a component appearing in almost all deciduous associations (with the single exception of river bank woodland) belonging to different alliances and orders of the *Querco-Fagetea* class.

2. Scots pine in the Sistema Ibérico

There are various Scots pine populations in the Sistema Ibérico mountain ranges:

2a. To the north of the province of Burgos and in Álava, on calcareous substrates.
2b. In the north of the Sistema Ibérico on acid lithologies in areas in the provinces of Burgos, Soria and La Rioja.
2c. Pinewoods in the south of the Sistema Ibérico can be subdivided into two large groups:

- one occurring in the provinces of Cuenca, Guadalajara and Teruel: the upper Tagus valley, on calcareous rocks, and on sandstone in the Sierra de Albarracín.
- another found between the Maestrazgo of Teruel (Gúdar and Javalambre) and Castellón (Peñagolosa), on both calcareous rocks and sandstones.
- The last group is found in the Ibérico-Levantinas mountains and those of the Catalan coast: the passes of Beceite between Castellón and Tarragona, on calcareous substrates, and some stands in the north of the latter province, on sandstones, in the Sierra de Prades.

2a. Pinewoods located in the area between Burgos and Álava provinces

The pinewoods situated in the provinces of Álava and Burgos are, according to Aseguinolaza *et al.* (1989), «the north-western vanguard of the Sistema Ibérico. These authors described the Álava pinewoods, situated between 600-700 m and 1,100 m, and concurred on their autochthonous origin. They also considered that these stands are mostly natural (as can be seen in table 2), and have become established in these areas, taking ad-

TABLE 2

THE PINEWOODS OF *Pinus sylvestris* IN NORTH SISTEMA IBÉRICO

Los pinares de Pinus sylvestris en el norte del Sistema Ibérico

Scots pine forests of north Sistema Ibérico	acid substrates between 1000 and 1900 m	Navarro (1986) Rivas-Martínez (1964, 1987); Gómez-Lobo (1997) y Loidi *et al.* (1997a and b)	López Gómez (1955, 1983); Costa Tenorio *et al.* (eds.) (1997) (in part): pinewood invasion of the potential area of broadleaves	Montserrat (1976); Peñalba (1989) y Charle Crespo (1993)
		Potential area above 1700 or 1800 m: *Vaccinio-Juniperetum nanae pinetosum sylvestris*		Potential area above 1200 or 1400 m (depending upon authors and sites)
Scots pine forests located in the mountain between Burgos and Álava	basic substrates mainly, between 600-700 and 1100 m	Catón Santarén & Uribe-Echebarría (1980); Aseguinolaza *et al.* (1989). Natural pinewoods: sometimes climax woodland, but mainly of secondary character.		

vantage of a certain degree of continentality in the climate. Catón Santarén and Uribe-Echebarría (1980) class some pinewoods within natural vegetation types such as pinewood with box (*Buxus sempervirens*) in south-western Álava, but consider that the majority are of a secondary character, and have spread through the combined effect of grazing and other human activities.

Aseguinolaza *et al.* (1989) consider that the pinewoods play an important ecological role as a serial community in the restoration of degraded land, «since it is the tree which establishes itself in very degraded scrubland, binding the soil to some extent and fostering the natural succession towards more mature stages». While they believe this to be a potential area for quejigo oak (*Quercus faginea*), beech or rebollo oak (*Quercus pyrenaica*) woods, they regard the pine as autochthonous. It survives naturally in this area, on open sites such as on crags or large boulders in what are termed «floating pinewoods», or even within other types of woodland, ready to colonise clearings caused by felling or fire. They confirm that pines in this region are mixed with quejigo and rebollo oak, beech and even holm oak, which other authors have attributed to the influence of direct and indirect human actions.

Perhaps the difficulty of interpreting these pinewoods is a consequence of the concept of the potential natural landscape being composed of a number of theoretical vegetation communities. All these authors recognise natural woods of Scots pine, while at the same time employing a classification scheme which denies their potential long-term development. They therefore conclude that most pinewoods in Álava province are successional communities to various broadleaf types such as, beech, quejigo and rebollo oak. A surprising note is that these woods are considered natural formations without having been

subjected to any type of syntaxonomic treatment. Other authors hold a more restricted view of the role of the pinewoods. For example, Loidi *et al.* (1997a and b) analysed the vegetation of the north-central part of the Iberian peninsula, but in the sections dealing with Álava do not comment on the pinewoods, probably as they are regarded as being of human origin.

2b. Pinewoods of the northern Sistema Ibérico

In this mountain range pinewoods are found between 1,000 m and 1,900 m. A survey of the botanical literature shows notable differences of opinion between the authors who have studied and interpreted these forests, as can be seen in table 2. One group of authors holds that the potential area of the pinewoods is above 1700-1800 m (though recently the odd exception has been recognised). The other maintains that the potential area of Scots pine is considerably greater, beginning at 1,200 m or 1,400 m (depending on the author and the site).

Within the first group there are two different tendencies. There is that best represented by López Gómez (1955, 1983), a strong supporter of the hypothesis of the anthropogenic expansion of pinewoods in the Iberian peninsula (northern Sistema Ibérico and the Sistema Central). He believes that there is a pseudo-climax phase, a «very stable so-called pinewood phase», resulting from the invasion by conifers of the potential area of the broadleaves and not from artificial reforestation. The other is the view held by most contemporary botanists, which states that these pinewoods originate from direct reforestation, often «very ancient» (Navarro, 1986).

These differences in opinion influence the interpretation of vegetation dynamics and the role of the various vegetation communities. Thus, according to the theory of López Gómez (1955), partially readopted by Costa Tenorio *et al.* (1997), the pinewoods found at elevations below their potential area would also be natural, and function as a serial community. The same pinewoods are defined by Navarro (1986), however, as «pine plantations», reforestations in the domain of oak and beechwoods. They are thus ignored from the phytosociological view, and do not figure in his study. This view has been shared by a number of authors since 1964, when Rivas-Martínez included the oro-Mediterranean [6] pinewoods of the Sierra de Neila within the oro-Mediterranean sub-association *Vaccinio-Juniperetum nanae* Rivas-Martínez 1964 *pinetosum sylvestris* (belonging to the *Pino-Juniperetea* Rivas-Martínez 1964, class) situated, according to aspect, above 1,750-1,850 m. Their structure in the Sierra de Urbión and Sierra de Neila is that of an open woodland with creeping juniper and bilberry [*Vaccinium myrtillus*] (...) especially in the middle or lower altitudes of the association» (Navarro, 1986).

Gómez-Lobo (1997) and Loidi *et al.* (1997a and b), without taking into account Peñalba's (1989) work, which we shall be discussing later, regard the pinewoods of the northern Sistema Ibérico as natural and climax vegetation only in the altitudinal zone from 1,600-1,700 or even 1800 metres up to 1900 metres, with those at lower altitudes having been reforested by man. Loidi *et al.* (1997a, 1997b) agree with the hypothesis of

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[6] For Bioclimatic terminology (supra-Mediterranean, oro-Mediterraenan and Montane biclimatic belts) see Rivas-Martínez (1982, 1983).

the artificial expansion, below 1,700-1,800 m, of pinewoods in the mountains of the northern Sistema Ibérico (Ibérico-Soriano sector [7]), which they term «timber plantations». They judge that these are occupying «the vast majority» of the potential area of supra-Mediterranean rebollo oak, and of some beechwoods, and that many of these «dense forests of *Pinus sylvestris* var. *iberica»* survive thanks to «management favouring this species rather than those of the potential forest».

However, these authors do accept that, exceptionally, some pinewoods below the potential altitude zone, «may be considered natural in a similar way to that recognised in the Guadarrama mountain». Such pinewoods are those in more continental conditions or in disadvantaged, geographically ecotonal sites such as hilltops or spurs of the Urbión section of the range. They nevertheless point out that «this does not mean that all the *Pinus sylvestris* var. *iberica* pinewoods of the Urbión mountain are natural, since in this area there has been a long history of human activity favouring the pine against other types of wood». For this reason they perceive the presence in the supra-Mediterranean belt of an association termed *«Galio rotundifolii-Pinetum ibericae* Rivas-Martínez & J. A. Molina 1997», with a tree canopy of Scots pine.

Other authors, however, have arrived at very different conclusions. Montserrat (1976), studying the climate and its relationship with vegetal communities in the Ebro valley, states that the presence of Scots pine in these mountains has to be attributed to climatic, not human causes. Later, Peñalba (1989) and Charle (1993) brought together a series of palynological and historical data that indicate the natural origin of most of these pinewoods.

Peñalba (1989) studied the palynological sequences obtained from cores bored in the provinces of Navarra, Vizcaya, Santander, Guipúzcoa, Álava and Burgos. She believed that the palynological sequences of *Pinus* from the different cores were from *Pinus sylvestris*, since their regional distribution coincided with that of the present day, very abundant in the Cordillera Ibérica but absent on the Atlantic-facing sides of the mountains of the Basque Country. The author believed this information invalidated existing maps of potential vegetation, since «the Holocene sequence of Quintanar de la Sierra demonstrates the omnipresence of *Pinus* in the region throughout the Holocene, which suggests the existence of a montane Mediterranean layer of autochthonous vegetation consisting of *Pinus* (probably *Pinus sylvestris*), and not the invasion of beech and oak woods by pine, linked to human activity, as appears in the maps of potential vegetation». At the same time, «a comparison with the sequences obtained from the northern region (i.e. the Atlantic side of the range), where pine is very sparse, shows that the distribution area of *Pinus sylvestris* has not varied for 10,000 years».

2c. Southern Sistema Ibérico, Ibérico-Levantinas Mountains and Costero-Catalanas Mountains

Scots pine populations in this area are scattered among various mountain nuclei, as described by Font i Quer (1954): «in the mountains of Tarragona province, a height of 1,000 metres has been enough to ensure the survival of Scots pine, which forms the highest zone». In addition, «this same pine is to be found in the passes of Tortosa and Beceite,

[7] For biogeographic classification of the Iberian peninsula see Rivas-Martínez (1987).

in the high Maestrazgo and Peñagolosa, the Sierras of Gúdar, Javalambre and Albarracín as far as the Serranía de Cuenca» (*op. cit.)*. Bolòs (1987) also described these pinewoods: «in the passes of Beceite, which rise over 1400 m, and, somewhat less clearly, in the Prades massif, with increasing elevation the *Violo-Quercetum* is transformed into Scots pinewood. The floristic composition does not change much, but the woodland becomes richer in mountain species».

The phytosociological treatment of pinewoods in these mountains began in 1961 (table 3). Rivas Goday and Borja (1961) described those of the Maestrazgo (Gúdar and Javalambre) as the association *Junipero sabinae-Pinetum silvestris* Rivas Goday & Borja 1961 of the *Querco-Fagetea* class, later incorporated into the new *Pino-Juniperetea* class, created by Rivas-Martínez (1964a). This same author, in 1987, defined the *Junipero sabinae-Pineto sylvestris sigmetum* series as «oro-Mediterranean Maestrazgo-Cuenca basicole of savin juniper (*Juniperus sabina*)», which in its mature or climax state is an open woodland of pine with a dense shrubby storey. Geographically it stretches from the Maestrazgo of Teruel province (Gúdar and Jabalambre) and the Serranía de Cuenca (Sierra de San Felipe and the Montes Universales) (Peinado and Martínez Parras, 1985, 1987; Rivas-Martínez, 1987).

TABLE 3

PINEWOODS OF SOUTHERN SISTEMA IBÉRICO AND NEARBY MOUNTAINS

Pinares del sur del Sistema Ibérico y de las montañas cercanas

Maestrazgo (Gúdar and Javalambre); Penyagolosa	basic substrates	Rivas Goday and Borja 1961. *Junipero sabinae-Pinetum silvestris*. between 1500 and 1800 m Peinado & Martínez Parras (1985 and 1987) Rivas-Martínez (1987), Roselló (1994), Costa (1987: between 1650- 1700 m and the top)	Montserrat (1976) considers these pinewoods are natural in Sistema Ibérico above 1200- 1500 m
Sierras de Albarracín y de Orihuela del Tremedal	acid substrates	Font i Quer (1954)	
Penyagolosa, Alto Mijares (Castellón)	acid substrates	Vigo (1965) pine woods of the alliance *Deschampsio-Pinion*. Roselló (1994) above Mijares approx. 1.400 m: *Cephalanthero-Quercetum pyrenaicae pinetosum sylvestris* (Vigo 1968)	
Macizo de Prades and Puertos de Beceite (Tarragona)	acid substrates	Font i Quer (1954) Bolòs (1987)	

Concerning the elevational range of this series, various authors agree in locating the lower limit at 1,500 m and its upper limit at 1,800 m. Rivas-Martínez (1987) extends the upper limit up to the tops of all the limestone mountains of the Maestrazgo and the Montes Universales. This altitudinal range is similar throughout most of its distribution area, though Costa (1987) raises the lower limit in the case of natural pinewoods in Valencia province, maintaining that their potential area in Peñagolosa and El Rincón de Ademuz is between 1,650-1,700 m and the summits. These authors do not comment on pinewoods found below the proposed lower limit for the *Junipero sabinae-Pinetum sylvestris* association, nor on those which occur on acid substrates in enclaves, such as those referred to by Font i Quer (1954) in the Sierra de Albarracín and the Sierra de Orihuela del Tremedal, probably because they regard them as being of artificial origin.

However, Montserrat (1976) attributed the presence of these pinewoods to ecological factors. When comparing Pyrenean stands with the very similar extensive pine forests of Covaleda-Vinuesa (on the southern slopes of the Sierra de Urbión) and with Cuenca-Teruel, it was found that: «towards the Cordillera Ibérica (Soria, Guadalajara, Teruel-Cuenca), and rising in altitude, continentality and summer rainfall increase, while winter precipitation falls; this all favours *Pinus sylvestris* woods, which dominate from 1,200-1,500 m upwards».

Vigo (1965) notes that the rebollo oak woods on the northern slopes of the high siliceous areas of Peñagolosa (Castellón) are replaced by pinewoods of the *Deschampsio-Pinion* alliance. Roselló (1994) shows that the only clearly natural *Pinus sylvestris* L. populations in the upper Mijares area of Castellón province are to be found in Santa Bárbara de Pina (Pina de Montalgrao at about 1,400 m). These are communities which would form a special rebollo oak wood sub-association on that summit: *Cephalanthero-Quercetum pyrenaicae* O. Bolòs & Vigo in O. Bolòs 1967 *pinetosum sylvestris* Vigo 1968, of the *Querco-Fagetea* class, which describes a shrubby formation of rebollo oak with a Scots pine canopy growing on red sandstone. It is also noted that the association *Junipero sabinae-Pinetum sylvestris* is present on the Monte Cruces at 1,710 m between Castellón and Teruel; this forms the link between the Scots pine woods of the Maestrazgo and nearby Peñagolosa and those of Gúdar and Javalambre.

3. Scots pine in the Sistema Central

In general the Scots pine woods of the Sistema Central are to be found from between 1,200-1,400 m to over 2,000 m. Ceballos *et al.* (1966) mapped the area, showing most of the pinewoods in the central area of the mountain range, in the Sierra de Guadarrama, in the provinces of Ávila, Segovia and Madrid. At the eastern end of the range and forming a link with the Sistema Ibérico, there are stands in the Serranía de Atienza, including the Sierra de Alto Rey, Sierra de Pela and the Mesa de Campisábalos. There is also a third, smaller nucleus of pinewoods in the Sierra de Gredos on the northern edge of the range between Hoyos del Espino and Navarredonda de Gredos. There are also occasional smaller populations like the stands further east: the Pinar de Hoyocasero [8], San Martín del Pimpollar and the Puerto del Pico, and a number of small stands and isolated individuals (Génova *et al.* 1988). Apart from the pinewoods of the Mesa de Campisábalos and the Si-

[8] The Pinar de Hoyocasero does not appear on the map produced by Ceballos *et al.* (1966).

erra de Pela which grow on limestone, the rest are found on acid substrates. Somewhat isolated from the stands on the mountain range there are some enclaves near the River Cega, on sandy ground in Lastras de Cuellar, in Segovia province, on the Castilian *meseta* (Costa Tenorio *et al.* 1997).

Most contemporary authors [9], in line with studies by Rivas-Martínez (1963, 1964a, 1987), do not believe that all these woods are of natural origin. A clear distinction has been drawn between those which are regarded as natural pinewoods (only those of the Sierra de Guadarrama above 1,600-1,700 m) which have received phytosociological attention (e.g. Table 4), and the pinewoods of other mountains in the Sistema. The latter are considered to be artificial, originating from ancient reforestations, and which therefore

TABLE 4

DIFFERENT OPINIONS ON THE CLASSIFICATION OF *Pinus sylvestris* FORESTS IN THE SISTEMA CENTRAL

Clasificación de los pinares de Pinus sylvestris en el Sistema Central

		Some authors from the Rivas-Martínez school	Martínez García (1999)
acid substrates between 1300-1400 m and 2000 m	**Sierra de Gredos**		– xero-mesophile of the west – mesophile – orophile
	Sierra de Guadarrama	Natural stands above 1.650-1.700 m 2. *Avenello ibericae-Pinetum ibericae* (Rivas-Martínez 1963) Rivas-Martínez & Molina abril 1997 2. *Galio rotundifolii-Pinetum ibericae* Rivas-Martínez & Molina abril 1997	– mesophile – orophile – xero-thermophile of the centre and east
	Sierra de Alto Rey		– mesophile – orophile – xero-thermophile of the centre and west – meso-xerophile of the west
basic substrates 1300-1500 m	**Sierra de Pela and Mesa de Campisábalos**		– calcicolous

[9] We should point out that these are the ideas generally accepted by authors of recent decades, as there are substantial differences between these and those held by earlier authors (Martínez García, 1999).

have not been assigned any phytosociological status. The zone they occupy has normally been defined as a potential area for *Quercus pyrenaica* forest, except that of the Serranía de Atienza, which for edaphic reasons is regarded as a potential site for *Juniperus thurifera* forest (Rivas-Martínez, 1987). Occasionally, some pinewoods of the Sierra de Guadarrama situated below 1,600 m have been interpreted as resulting from natural colonisation due to direct or indirect human influences (Costa, 1974).

In 1956, Rivas Goday described for the first time the high mountain pinewoods as being within the *Junipero-Sarothamnetum purgantis* association. In 1963, Rivas-Martínez modified this (*Junipero-Sarothamnetum purgantis* (Rivas Goday 1955) em. Rivas-Martínez) and assigned it to an extensive area. Its limits vary considerably according to aspect and to human and animal influences. Two sub-associations were distinguished: typical ((196>1,800) 2,000-2,250 m), and *Juniperus communis* L. subsp. *alpina* (Suter) Celak (above 2,100 m); and the sub-association *pinetosum silvestris*, which in turn has two sub-associations: typical (1,750-2,100 m) and that of *Genista florida* L. (1,500-1,750 m). After a series of changes of nomenclature and taxonomy, Rivas-Martínez *et al.* (1987a) proposed various sub-associations within the oro-Mediterranean association *Junipero nanae-Cytisetum oromediterranei* Rivas-Martínez 1963 *corr.* Among these sub-associations are: *adenocarpetosum hispanici* Rivas-Martínez *et al.* 1987, including «those pinewoods or *Cytisus* scrublands distinguished by the presence of *Adenocarpus hispanicus»*; *arctostaphyletosum crassifoliae* Rivas-Martínez *et al.* 1987; *populetosum tremulae* Rivas-Martínez *et al.* 1987 and *genistetosum cinerascentis* Rivas-Martínez *et al.* 1987. They noted differential species of the last three sub-associations including some ecological and chorological data, but nothing about the tree canopy. In the data tables, however, *Pinus iberica* [10] appears with a cover rate up to 4 in the *Holosyntypus* inventories, according to the Braun-Blanquet index (Braun-Blanquet, 1979). Within the syntaxonomic scheme, the existence of pinewoods is hidden behind the terminology of different types of scrubland.

Something similar occurs in the study of Rivas-Martínez and Cantó (1987), which describes three communities in which the Scots pine is found, but without a clear, ecological, dynamic and syntaxonomic sense. One is the previously mentioned oro-Mediterranean sub-association *Junipero nanae-Cytisetum oromediterranei* Rivas-Martínez 1963 *corr.* Rivas-Martínez *et al.* 1986 *arctostaphyletosum crassifoliae* Rivas-Martínez *et al.* 1986 of the western area of the Sierra de Guadarrama, which «may be structurally presented as either *Cytisus* scrubland or pinewood». The other two are associations found in the supra-Mediterranean belt:

1. *Erico-Arctostaphyletum crassifoliae* Rivas-Martínez 1968, (*Cisto-Lavanduletea* Br.-Bl. 1940 class) of which they state that «on these sites, Scots pine (*Pinus sylvestris* var. *iberica*) is usually natural, above all in the sub-association with creeping juniper (*juniperetosum nanae = juniperetosum hemisphaericae* Costa 1974 *corr.*)».
2. *Adenocarpo hispanici-Genistetum floridae* Rivas-Martínez *et al.* 1974 (*Cytisetea scopario-striati* Rivas-Martínez *et al.* 1964 class) including *«Pinus iberica».*

In 1991 Fernández-González published a study of the vegetation of the Valle de El Paular (Sierra de Guadarrama) in which he revised all the sub-associations (except, of

[10] *Pinus iberica* is *Pinus sylvestris* L. var. *iberica* Svob.

course the typical sub-association) which had been defined by Rivas-Martínez *et al.* (1987a) within the association *Junipero nanae-Cytisetum oromediterranei.* He distinguishes:

a) *juniperetosum nanae* (Rivas-Martínez 1970) Rivas-Martínez and F. Fernández-González 1991;
b) *cytisetosum oromediterranei*;
c) *adenocarpetosum hispanici* (Rivas-Martínez, Belmonte, Cantó, F. Fernández-González, V. de la Fuente, J. M. Moreno, Sánchez-Mata and L. G. Sancho 1987) Rivas-Martínez and F. Fernández-González 1991;
d) *pinetosum sylvestris* (Rivas-Martínez 1963) Rivas-Martínez and F. Fernández-González 1991;
e) *populetosum tremulae* (Rivas-Martínez *et al.*, 1987a) Rivas-Martínez and F. Fernández-González 1991
f) *genistetosum cinerascentis* (Rivas-Martínez *et al.*, 1987a) Rivas-Martínez and F. Fernández-González 1991.

The natural pinewoods are grouped mainly in the sub-association *pinetosum sylvestris*, though sub-associations c, e and f can also have a pine canopy.

These authors state that all the above communities are located within the oro-Mediterranean belt. Fernández-González (1991), however, mentions a few exceptional locations when talking about the potentiality of the upper supra-Mediterranean belt, tipically attributed to *Luzulo forsteri-Quercetum pyrenaicae* Rivas-Martínez, 1962, «the case of a few upper supra-Mediterranean enclaves, in which birchwoods (*Melico-Betuletum celtibericae*) or Scots pine woods (*Senecioni-Cytisetum oromediterranei genistetosum cinerascentis*) have the role of potential vegetation». In another paragraph, moreover, he maintains that the «Scots pine can clearly develop in the upper supra-Mediterranean belt as a secondary tree». We interpret this role of secondary tree as meaning that pine fulfils a successional stage in the development of rebollo oak woods, though the author did not expressly define it as such. It seems contradictory neither to assign a syntaxonomic category to a community that is considered natural, nor to define its function in the series within which it is secondary.

Rivas-Martínez and Molina (1997) have recently made another proposal for changes to the phytosociological treatment of the pinewoods of the Guadarrama. These would be divided into two associations: *Avenello ibericae-Pinetum ibericae* (Rivas-Martínez 1963) *ass. nova* (= *Senecioni-Cytisetum oromediterranei* Tüxen & Oberdorfer 1958 *corr.* Rivas-Martínez 1987 *pinetosum sylvestris* (Rivas-Martínez 1963) Rivas-Martínez & Fernández-González 1991) and *Galio rotundifolii-Pinetum ibericae ass. nova.*

The main premise used by the «Rivas-Martínez school» in separating the two types of pinewood, and the resulting construction of a taxonomic system is that «ancient reforestations» have substantially and artificially extended the natural distribution of pinewoods to lower altitudes, to the disadvantage of rebollo oak and *Juniperus thurifera* woods. This argument, however, which has undoubted important geobotanical repercussions, has not been supported with objective data.

If anything, the opposite has been the case. Data from recent palynological studies, particularly that of Franco (1995), and historic ones (Luis López, 1987a, 1987b, 1989; Manuel Valdés *et al.,* 1993; Mancebo *et al.*, 1993; Manuel Valdés, 1993, 1996; Rojo and Montero, 1996; Martínez García, 1999) suggest that the map by Ceballos *et al.* (1966)

faithfully identifies the artificial and natural Scots pine stands in the Sistema Central. The area of natural stands is greater than that defined by Rivas-Martínez (1987), Rivas-Martínez *et al.* (1987a, 1987b), Rivas-Martínez and Cantó (1987) and many others. These studies show that there has been a band of Scots pine forest in the Cordillera Central throughout the late glacial, and that this was reduced first by the effects of climate and in recent centuries by human activity. We need to bear in mind that the massive reforestation campaigns which considerably increased the area occupied by this species got under way in Spain in 1940, increasing from the fifties onward, just a few years before the surveys carried out by Ceballos and his collaborators.

Using this information together with data classification and ordination performed by programs TWINSPAN (Hill 1979) and DECORANA (Hill 1979), respectively Martínez García (1999) classified the pinewoods considered natural by Ceballos *et al.* (1966), obtaining six types of pinewood (table 4). The internal variability of each type is important, as there are frequent forms of transition between them. We briefly describe below the different types, their position, and some of their characteristic species:

A. Acid Pinewoods

A.1. Xerophile Pinewoods

A.1.1. Orophile Pinewoods. These extend mainly from 1,500 m to the highest altitudes reached by trees in these mountains, on moderate to highly stony soils with little edaphic development. They are mostly to be found in the Sierra de Guadarrama, though there are examples to be found in the Sierra de Gredos and the Sierra de Alto Rey. The characteristic species most in evidence are *Cytisus oromediterraneus*, *Deschampsia flexuosa* subsp. *iberica* and *Juniperus communis* subsp. *alpina.* The internal variability of the group is important. Two subgroups can usually be distinguished: one representing the colder, drier forests, and the other comprising those pinewoods in transition towards easier ecological conditions.

A.1.2.1. Xero-thermophile pinewoods of the centre and east. These are found on the lower and middle slopes, mainly south-facing, from 1,300 m to a little over 1,700 m in the Sierra de Guadarrama and Sierra de Alto Rey. They grow on stony or very stony lithologies, with many rocky outcrops and poorly developed acid soils. The former mountains are composed of granites and gneisses and the latter of slates and quartzites. The main species belonging to this group include: *Genista cinerascens* Lange, *Cistus laurifolius* L., *Halimium umbellatum* (L.) Spach. subsp. *viscosum* (Willk.) O. Bolòs & Vigo, *Micropyrum tenellum* (L.) Link., *Lavandula stoechas* L. subsp. *pedunculata* (Miller) Samp. ex Rozeira, *Avenula sulcata* (Gay ex Boiss.) Dumort. subsp. *sulcata*, *Hieracium castellanum* Boiss. & Reuter, etc.

A.1.2.2. Xero-mesophile pinewoods of the west. These are to be found at the western end of the area studied, on the northern side of the Sierra de Gredos between 1,400 m and about 1,600 m, on acid rocks such as granite, with stony or very stony soils with little edaphic development. These ecological factors determine their separation from the mesophile pinewoods of A.2.1, to which they are nevertheless closely related. They are differentiated both in quality and quantity from the xero-thermophile pinewoods of group A.1.2.1 by *Festuca elegans* Boiss, a species only found in this sector of the mountains and

which gives the group its individual identity. Among the main species are *Cytisus scoparius* (L.) Link subsp. *scoparius* and *Santolina rosmarinifolia* L. subsp. *rosmarinifolia.* Other species, like *Centaurea amblensis* Graells or *Ornithogalum concinnum* (Salisb.) Coutinho, though not abundant, may, because of their area of distribution, play a role in distinguishing the pinewoods of the Sierra de Gredos.

A.2. Mesophile Pinewoods

A.2.1. Mesophile pinewoods. These are located in low to middle zones of the altitude range, especially between just under 1300 m and 1600 m (or higher in some enclaves), mainly in the Sierra de Guadarrama and Sierra de Gredos, and less in evidence in the Sierra de Alto Rey. They are found on deep, not usually stony soils, with no, or few, rocky outcrops. Their indicator species are *Pteridium aquilinum* (L.) Kuhn subsp. *aquilinum* and *Genista florida* L. subsp. *florida.* Among the common species distinguishing them from the other mesophile pinewoods are *Avenula sulcata* subsp. *sulcata*, *Ilex aquifolium* L., *Cerastium brachypetalum* Desportes ex Pers. subsp. *brachypetalum*, *Cynosurus elegans* Desf., *Holcus mollis* L. subsp. *mollis*, *Cardamine hirsuta* L., *Conopodium subcarneum* (Boiss. & Reuter) Boiss, *Galium rivulare* Boiss. & Reuter, *Ranunculus ollissiponensis* Pers., *Sanicula europaea* L., etc.

A.2.2. Meso-xerophile pinewoods of the east. These are found at the eastern end of the area studied, largely on the northern slopes of the Sierra de Alto Rey between about 1,350 m and 1,600 m, on substrates derived from quartzite and slates, with moderate to highly stony soils. The ecological similarities between the mesophile (A.2.1.) and the eastern meso-xerophile (A.2.2) pinewoods are marked by a series of common species which indicate that these two groups share some mesophilous characteristics. Among these some of the most significant are *Cruciata glabra* (L.) Ehrend., *Festuca* gr. *Rubra* L., *Galium rotundifolium* L., *Anthoxanthum odoratum* L., *Clinopodium vulgare* L. subsp. *vulgare*, *Fragaria vesca* L., *Geum sylvaticum* Pourret, *Luzula forsteri* (Sm.) DC., *Veronica officinalis* L. and *Viola riviniana* Rchb.

The differences between these two groups are due to their floristic and structural composition. There is in group A.2.2 an abundance of *Ericaceae*, heaths (*Erica arborea* L. and *Erica australis* L.), the bearberry bush (*Arctostaphylos uva-ursi* (L.) Sprengel) and common heather (*Calluna vulgaris* (L.) Hull.) - which we believe to be the result of the rock type on which these woods grow. These are slates and quartzite, the latter generating very poor soils. Another point is the significant presence in the A.2.2 group of species such as *Cistus laurifolius* and *Juniperus communis* L. subsp. *hemisphaerica* (K. Presl) Nyman, which indicate relatively drier conditions, perhaps related to the stoniness, than those characteristic of the A.2.1 group.

B. Calcicolous Pinewoods

These include all the pinewoods in the north-east of Guadalajara province, together with some small stands in the provinces of Segovia and Soria, growing on calcareous substrates between 1,300 m and a little over 1,500 m. These are woods we define as «pinewoods with juniper (*Juniperus communis* subsp. *hemisphaerica*)», which have de-

veloped on calcareous surfaces or outcropping rocks with very little edaphic development.

The species which distinguishes these is *Koeleria vallesiana* (Honckeny) Gaudin subsp. v*allesiana*, which appears in all the calcicolous woods but is absent in the acid pinewoods. Other species clearly preferring this substratum (in some cases they only appear in calcicolous pinewoods) are *Juniperus communis* subsp. *hemisphaerica*, *Helianthemum oelandicum* (L.) Dum. subsp. *incanum* (Willk.) G. López, *Potentilla cinerea* Chaix ex Vill., *Teucrium polium* L. subsp. *capitatum* (L.) Arcangeli, *Thymus izcoi* Rivas-Martínez, Molina & Navarro, *Avenula bromoides* (Gouan) H. Scholz subsp. *pauneroi* Romero Zarco, *Bromus erectus* Hudson subsp. *erectus*, *Coronilla minima* L., *Satureja cuneifolia* Ten. subsp. *intricata* (Lange) G. López & Muñoz Garmendia, *Teucrium chamaedrys* L.

4. The north-west of the Iberian peninsula and southern side of the Cordillera Cantábrica

The small enclaves of Scots pine in the north-west of the Iberian peninsula and the southern side of the Cordillera Cantábrica have been interpreted in recent decades as artificial stands created by human activity. For this reason, they have been little studied from the geobotanical point of view, and have received no phytosociological treatment. However, recent studies in this area, based on palynological analysis and on fossilised or sub-fossilised materials, indicate that these pinewoods are the remains of ancient woodlands established in these enclaves for the last 13,000 or 14,000 years. For example, García Antón *et al.* (1997) conclude that a mixed cover or a mosaic of both types of formations (*Quercus* and *Pinus*) must have shared dominance in the forest landscapes of this area for practically the whole of the Holocene. During this period there was an advance of *Quercus* at the expense of *Pinus* from the Cordillera Cantábrica to the Sistema Ibérico in accordance with the gradient of oceanic conditions and continentality. The presence of *Quercus* is most pronounced in the Cordillera Cantábrica, though it does not completely displace *Pinus.* On the southern side, *Quercus* is less in evidence than on the northern, though it did increase significantly after the first half of the Holocene.

Maldonado (1994) and Ramil *et al.* (1996) studied a more westerly zone than García Antón *et al.* (1997), the north-west of the Iberian peninsula, and obtained similar results that can be summed up:

1. In areas with greater oceanic influence (northern slopes, or more northerly mountains) the decline of the pinewoods took place during the early Holocene as a result of climatic changes.
2. In more Mediterranean and continental areas, in those inland mountain ranges reaching sufficient altitude to have a continental climate suitable for Scots pine, the disappearance of the pinewoods is very recent, perhaps as recent as the last millennium. The authors attribute this fact to the heavy deforestation carried out by man, since this is an area which has undergone profound transformation as Maldonado (1994) maintains: «the almost complete disappearance of the pinewoods on the southern side of the Cordillera Cantábrica has come about recently, as a result of human activity». (e.g. Sevilla (1997) also presents historical data on history, climate and forest dynamics, etc., which bear out the idea of the

disappearance of *P. sylvestris* due to human causes in the Cordillera Cantábrica, particularly on the south side.

The westernmost outlier, a living testimony of the westerly expansion of pinewoods across the Cordillera Cantábrica to the mountains of Galicia and northern Portugal, is in the Sierra de Gêrez (Portugal). Noted by Pereira Coutinho in 1913, these pines were later interpreted by Bellot (1950) as a relict of natural origin.

Somewhat further to the east, in the high basin of the River Porma (León), the species still occurs in the Pinar de Lillo. This is a small pinewood of 160 ha, with stands of birch, *Quercus petraea* and beech, sited between 1,300 m and 1,900 m on ortho-quartzites (Franco *et al.*, 1996) whose origin has been the subject of considerable discussion. Font i Quer (1954) briefly mentions the presence of *Pinus sylvestris* in Velilla de Guardo, Sierra del Brezo and Peñarredonda (Palencia); Ruiz de la Torre *et al.* (1983) also refer to these stands, without questioning their natural origin. Aedo *et al.* (1986) (table 5) consider the Pinar de Lillo to be a relict of the pinewoods which «formerly occupied large areas of the Cordillera Cantábrica and have since disappeared», though they believe that this disappearance may be related to climatic changes and the appearance of *Fagus sylvatica* and *Quercus* species.

Though there are references dating from ancient times, there are few geobotanical studies about this topic. Rivas-Martínez (1964a, 1964b) consider it as a natural stand with paraclimax character like we could find in Rivas-Martínez (1964a): «the upper Porma valley, on the western side of the Señales pass, is an outstanding landmark on the siliceous Cordillera; here, because of an easily podzolizable substratum and a relatively less oceanic climate, the birchwood gives way to *Pinus sylvestris.* We regard the pinewood in question as a paraclimax of *Blechno-Fagetum.* From a systematic-sociological standpoint, we cannot differentiate more than one *pinetosum* sub-association (dif. *Pinus sylvestris*, *Blechnum spicant*, *Euphorbia hiberna*, *Hieracium sabaudum*) *Blechno-Fagetum pinetosum* Rivas Mart. 1964» (table 5).

TABLE 5

THE PINEWOODS OF *Pinus sylvestris* IN THE CORDILLERA CANTÁBRICA

Pinares de Pinus sylvestris en la Cordillera Cantábrica

Pinewoods of Lillo	quartzite rocks between 1300-1750 m	Rivas-Martínez (1964a and b): *Blechno-Fagetum pinetosum*. Pseudo-climax natural pinewoods	Relict pinewood: Aedo *et al.* (1986), Sánchez Hernando (1992), Franco Múgica *et al*. (1996) and García Antón *et al*. (1997), Sánchez Hernando *et al.* (1999)

A number of botanists have ruled out this stand as being of natural origin, and the belief that it was planted has gained ground. However, Sánchez Hernando (1992) found sub-fossilised remains (wood, cones, etc.) from the Pinar de Lillo from *Pinus sylvestris* and *Betula* to be aged at 4,386 ± 50 years BP. In further work, Sánchez Hernando *et al.* (1999) extended the earlier study to look at the southern side of the Cordillera Cantábrica analysing the samples obtained in two further deposits with sub-fossilised cones and

wood from Scots pine and birch. The dates obtained were 2,360 ± 50 and 1,530 ± 50 years BP. Franco *et al.* (1996) and García Antón *et al.* (1997), analysed a peat sample which confirmed the natural and continuous presence of *Pinus* over the last 1,700 years. These data convince us that this wood is of natural origin.

5. Scots pine in the Sierras Béticas

The few Scots pine stands in the Sierras Béticas are situated in the Sierra de Baza and the Sierra Nevada, all on calcareous substrates. About these Font i Quer wrote in 1954: «the most likely scenario is that if, in the 1,600 metres of the upper siliceous cap of the Sierra Nevada, there once was a belt of coniferous trees, it would have been the Scots pine which formed it». Subsequent authors have generally agreed with this statement.

In 1987 Rivas-Martínez defined the oro-Mediterranean series of the *Juniperus sabina* on alkaline soils from the Sierras Béticas as *Daphno oleoidi-Pinetum sylvestris S.* Rivas-Martínez 1964. He considers that this association in its mature state is that of an open pinewood, situated above 1,700 m «on the high calcareous massifs of the Betic bio-geographical province». He describes for the acid areas the Nevada siliceous oro-Mediterranean series of creeping juniper *Genisto baeticae-Junipereto nanae sigmetum*, whose climax state is a dense scrub ruling out the presence of Scots pine. However, he speculates that «it may, in historical times, have also been covered by an arboreal storey of pines (*Pinus sylvestris* var. *nevadensis*), now non-existent».

Regarding the altitudinal range of the alkaline series, Peinado and Martínez Parras (1985) and Losa Quintana *et al.* (1986) consider that this occupies the high areas of the Sierras Béticas, above 1,600 m in the north and between about 1,700-1,800 and 2,100 m in the furthest south. Pérez Raya *et al.* (1990) raise the lower limit of the series, considering this to be from 1,900 m upwards. However, the series or some of its associations may extend lower and occupy certain upper parts of the supra-Mediterranean belt, because of particular topographical reasons which hinder the development of evergreen oakwoods. Blanca and Morales (1991) are of the same opinion, affirming that the mountain pinewoods of the Sierra de Baza are optimally situated in the oro-Mediterranean belt from 1,800-1,900 m, depending on their orientation.

The final stage of this series, according to its geographical position, may be woodland of *Pinus nigra* Arnold. subsp. *salzmannii* (Dunal) Franco as in Cazorla, Segura, Alcaraz and Mágina, or *Pinus sylvestris* var. *nevadensis* as in Baza and Sierra Nevada (Peinado and Martínez Parras, 1985; Losa Quintana *et al.*, 1986; Blanca and Morales, 1991). However, Costa Tenorio *et al.* (1997) present a different hypothesis. They consider that Scots pine occupies special «marginal» areas such as cool shady river valley floors, while «the true domain of the upper forest zone» belongs to «the black pine, more favoured by the cold dry continental climate of the summits of these southern mountains», even though normally the upper forest area of the Sierra Nevada and Sierra de Baza has normally been regarded as a potential zone for *Pinus sylvestris* var. *nevadensis.*

Discussion and conclusions

During the review of the existing geobotanic and phytosociological bibliography of the Scots pine stands, we verified a notable difference of the criteria used to interpret their

origin (natural or artificial) and their role (climax, serial stage or simply plantations in areas that do not correspond), especially for those, which are grown in lower altitudes. Consequently, the Iberian pinewoods appear in a disperse form in the bibliography in different sintaxonomic units.

Data and units dispersion and the absence of a criteria unit in typology make it difficult to carry on any study of the totality of the Iberian pinewoods. For this reason, a compilation of the most significant works has been done covering an explanation and analysis of the basic arguments used by each author.

Most of the authors base their classification of their communities on the fundamental idea that there are two types of pine woods: the natural and the artificial ones. The latter have been created by man via massive plantations of the species in the past. Based on Palynological and historical data this hypothesis has been discussed and rejected during the last years, for some important populations of this species, located in the Sistema Central, Sistema Ibérico and Cordillera Cantábrica. This means a radical change in the concept of what these pinewoods are, making it possible to recognise natural formations that have not been studied because it was thought that they were not natural. Something similar might have happened with the rest of Iberian pine stands.

Due to these important changes we believe that it is necessary to carry out a phytoecological classification of the Iberian pine formations, which in order to be coherent and lasting it should start using as base material the palynological and historical data, rejecting every *a priori* conception on their origin.

From a practical point of view, the possibility of using a Scots pinewood typology of the Iberian peninsula should be the starting point to plan the management and the silviculture treatment and its intensity most suitable for each pine stand. At the same time, the knowledge and the geographical location of the different types of pinewoods are essential to translate results from the different silvicultural experiences.

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RESUMEN

Tipología de las masas de *Pinus sylvestris* en España

La gran variedad de factores ecológicos: tipos de clima, suelos, topografía, posición geográfica, etc., que existen en la Península Ibérica han generado una gran diversidad de comunidades presididas por *Pinus sylvestris* L. En este trabajo situamos las formaciones presentes en España y analizamos las diferentes interpretaciones geobotánicas que de ellas han realizado los botánicos españoles. No existe pues unanimidad a la hora de establecer una tipología de estos bosques, muchos de los cuales no han recibido tratamiento geobotánico o fitosociológico al ser considerados como meras repoblaciones en áreas consideradas como potenciales de otras especies.

PALABRAS CLAVE: *Pinus sylvestris* L.
Tipología
Geobotánica
Fitosociología
España

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